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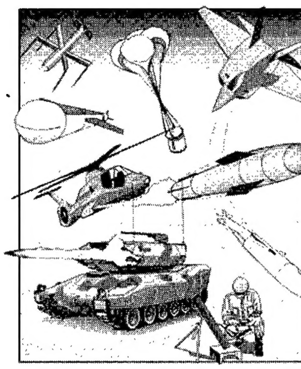
Electromagnetic Spectrum Selection for Missile Seekers

Tutorial



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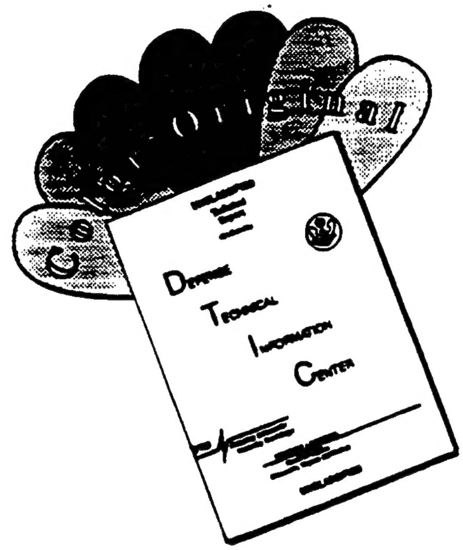

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13. ABSTRACT (*Maximum 200 words*)

The implementation of an autonomous smart weapon system, such as surface/air-to-air or surface/air-to-ground missiles presents an engineering challenge to the system and seeker/sensor designers. This is due to a wide variety of targets, backgrounds, countermeasures, and weather conditions expected for each scenario. The seeker/sensor design requires engineering tradeoffs by the designers, such as size constraints, detection/tracking performance, and search volume to name a few. All of these tradeoffs tend to determine the selection of the electromagnetic spectrum by which the seeker/sensor will operate. Therefore, this document presents a tutorial on the electromagnetic spectrum selection for missile seekers.

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Foreword

Technology is an important ingredient in having an effective military. Technology provides the military with advanced capabilities in communications resulting in rapid response as well as precision strike weapon systems resulting in robust effectiveness. As technology matures, more and more "smart" systems will evolve. The unique operational and technical nature of these smart systems has given rise to a variety of sensor/seeker technologies available to the designer.

There is no "one" perfect sensor technology to be used in a missile seeker system, but instead there is in many cases "one" better technology given the constraints. This document was written as a tutorial for those who wish to develop an understanding as to the selection of a particular technology implemented in autonomous missile sensor/seeker designs.

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1.0 INTRODUCTION

The implementation of an autonomous smart weapon system, such as surface/air-to-air or surface/air-to-ground missiles presents an engineering challenge to the system and seeker/sensor designers. Achievement of objectives may require missiles employing single as well as multi-spectral seekers.

The selection of the electromagnetic spectrum(s) to be used by the seeker requires engineering tradeoffs by the designers. These tradeoffs involve many variables such as missile diameter/volume constraints, acquisition range/tracking accuracies, target position uncertainty (which drives search volume requirements), target(s) characteristics (size, temperature, radar cross section, velocity, altitude), natural background (sky, ground, trees, dust, rural/urban, seasonal, night/day), weather (rain, clouds, fog, snow), and countermeasures (signature suppression, decoys, jammers).

2.0 ELECTROMAGNETIC SPECTRUM DISCUSSIONS

The seeker links the missile to the outside world and is used to detect and track targets. The sensor is sensitive to the electromagnetic radiation incident upon its aperture. This radiant energy can come from any of the following sources: reflection from the target, emittance from the target, and/or emittance/reflectance from the target's background (rocks, trees, sun, clouds, etc.). In response to this energy, the sensor produces internal electrical signals which are sent to the signal processing electronics. The sensor output is processed for target detection and possibly recognition by the electronics to determine the appropriate guidance commands for missile intercept. A simplified diagram is shown in Figure 1.

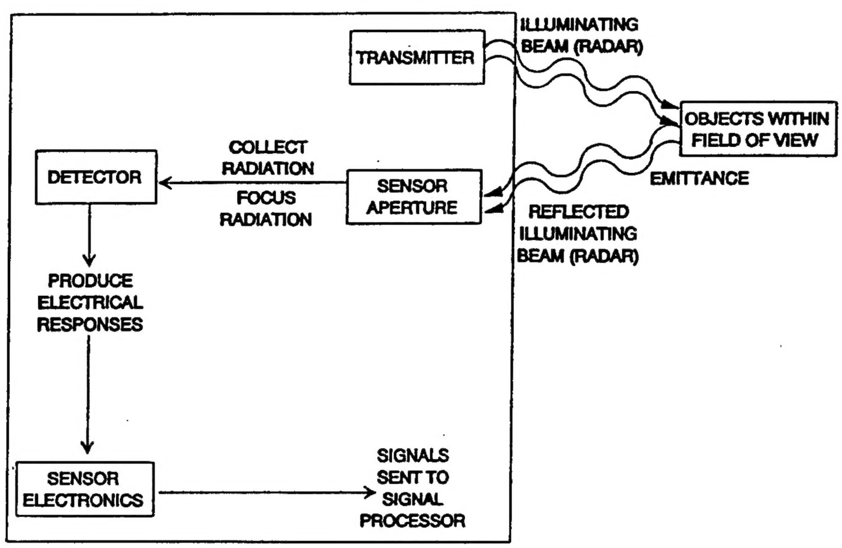


Figure 1. Simplified Radar/Infrared Sensor Block Diagram

The electromagnetic spectrum can be partitioned into radio frequency and infrared wavebands as illustrated on the horizontal axis of Figure 2. One important aspect of spectrum selection for a seeker is consideration of the associated atmospheric attenuation that is indicated on the vertical axis of Figure 2. The desirable points on the curve are the valleys (marked with a circle) which correspond to wavebands of minimum atmospheric attenuation or "atmospheric windows" as they are commonly referred to.

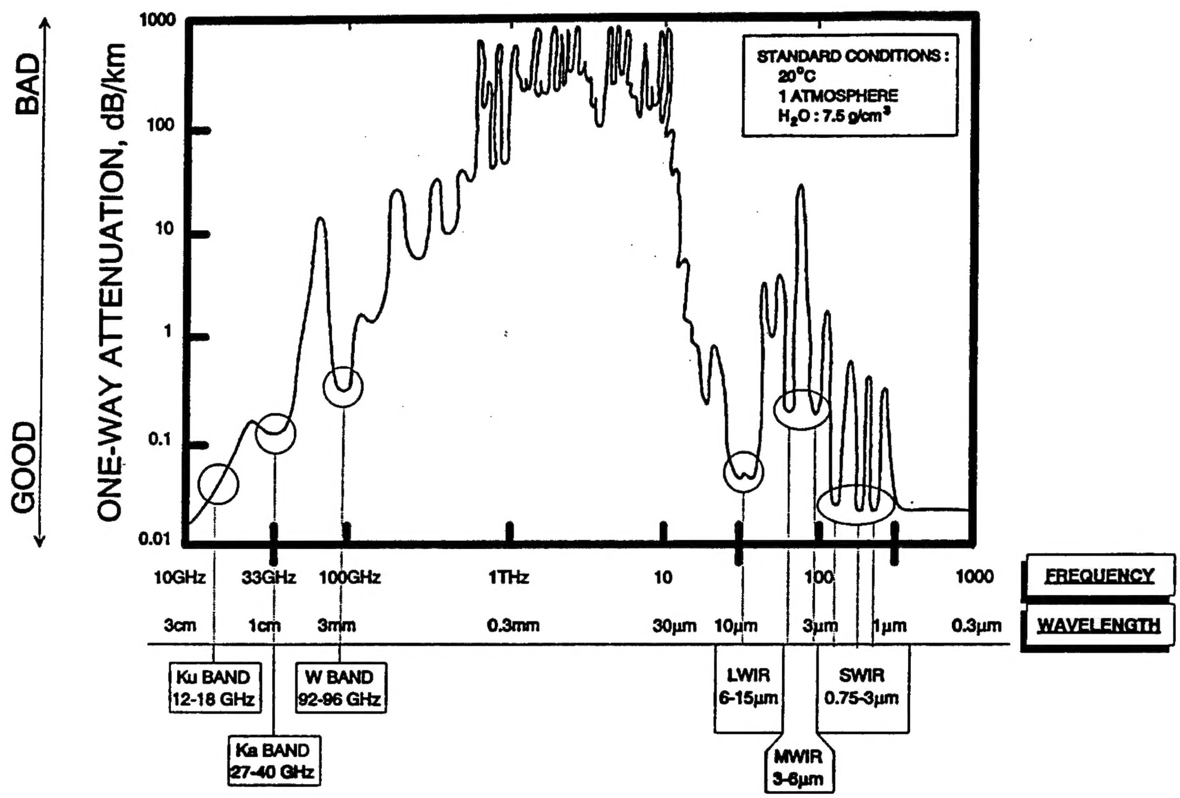


Figure 2. Electromagnetic Spectrum

Accordingly, the common nominal infrared wavebands are 0.75-3 μm (short wave IR), 3-6 μm (mid wave IR), and 6-15 μm (long wave IR). The corresponding common nominal radio frequency bands are 9-12 GHz (X band), 12-18 GHz (Ku band), 27-40 GHz (Ka band), and 92-96 GHz (W band). The 35 and 94 GHz regions are commonly referred to as millimeter wave frequencies by the seeker community. Appendix A contains a much broader electromagnetic spectrum which covers all sensor technologies.

2.1 Infrared

All objects possessing a temperature above absolute zero (minus 459.67 degrees fahrenheit) emit radiation. This thermally generated radiation occurs in all regions of the IR

spectrum. The amount of IR radiation from a particular waveband is a function of the temperature and material characteristics of an object such as emissivity (the ability to emit radiation). An ideal radiator is called a blackbody which possesses an emissivity of "one" (ideal). Plank's law provides the spectral radiant emittance of a blackbody as a function of temperature. Figure 3 shows the distribution of radiant emittance as a function of wavelength for a blackbody at various temperatures. The bottom portion has been rescaled to show the emittance of the various wavelengths at cooler temperatures.

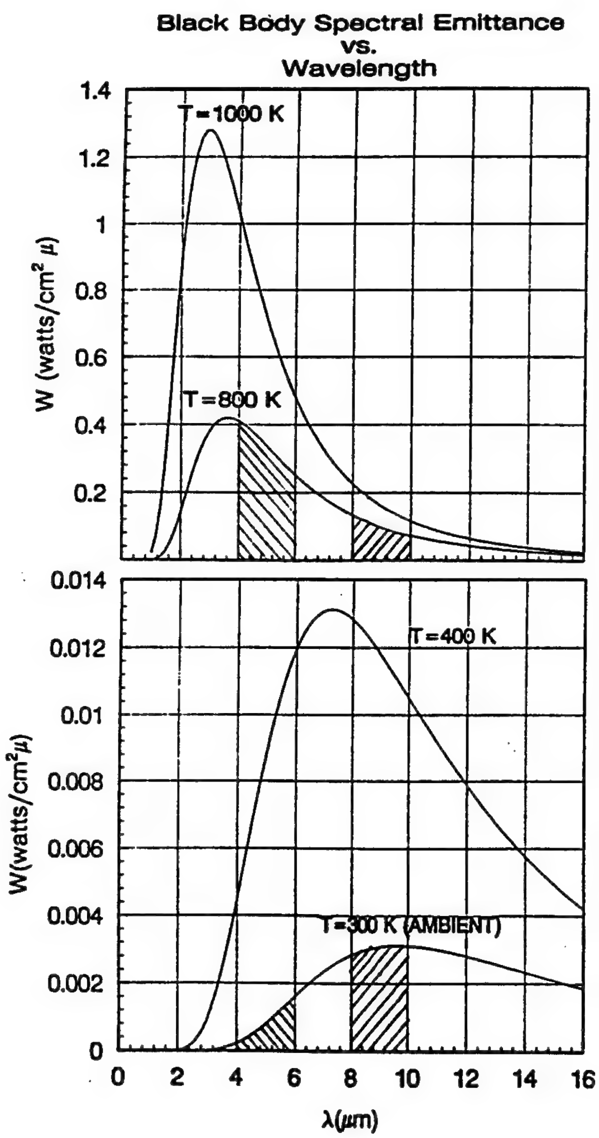


Figure 3. Emittance vs Wavelength For Specific Temperatures

The area under a particular temperature curve over the waveband of interest determines the amount of spectral emittance in that region of the spectrum. The spectral emittance resident in the 4-6 μm and 8-10 μm wavebands at 300° K are illustrated by the shaded areas in Figure 3. At lower temperatures there is considerably more energy in the 6-15 μm region than in the 3-6 μm region. For example at 80.3°F (300°K-ambient) approximately 38% of the total radiation is in the 6-15 μm region as compared to 1.3% in the 3-6 μm and 0.009% in the 0.75-3 μm regions. Consequently, the 6-15 μm region generally performs better against a cooler target than 3-6 μm and 0.75-3 μm regions. However, as the temperature is increased the percentage of the emittance in the .75-3 μm and 3-6 μm regions increase with a corresponding percentage decrease in the 6-15 μm region. At these hotter temperatures the 3-6 μm region performs better than the 6-15 μm and the 0.75-3 μm regions. At very hot temperatures (>1200°K) the percentage of emittance is greater for the 0.75-3 μm region as compared to 3-6 μm and 6-15 μm regions.

The 0.75-3 μm region is not normally used in "passive" missile seeker applications because typical targets (at temps less than 1000°K) passively emit "thermal radiation" which is characteristic in the mid/long wave IR bands. However, the 0.75-3 μm region is used in "active" or "semi-active" missile seeker systems which require a source designator such as a LASER. Most LASER sources used produce stimulated radiation emissions in the 0.75-3 μm window.

The advantages and disadvantages of the two IR spectral regions commonly used for "passive" missile seekers is shown in Table 1.

Table 1. Comparison of IR Regions

Spectrum Region	Advantages	Disadvantages
3-6 μm (MWIR)	• Responsive to hotspots • Good contrast with hot object against an ambient background • Technology is very mature/low cost • Multiple detector material selection • More design tolerance	• Poorer performance against cool targets • Atmospheric attenuation (under the conditions specified in Figure 2. See note 1).
6-15 μm (LWIR)	• Responsive to cool targets • Less atmospheric attenuation (under the conditions specified in Figure 2. See Note 1)	• Technology not as mature/higher cost • Limited detector material selection

Note 1: Atmospheric attenuation is heavily dependent upon range, temperature and humidity. Regions of crossover exists where MWIR attenuation is lower than LWIR.

IR seekers can be used in scanning or staring modes. LWIR scanning systems would have better performance than MWIR scanning systems. However, MWIR staring systems with longer integration times may provide the needed performance.

2.2 Radio Frequencies (RF)

Radio frequency selection involves engineering tradeoffs among several critical factors which impact seeker characteristics and performance. These factors include physical size, transmit power, bandwidth, beamwidth, atmospheric attenuation, cost, and maturity of components. Table 2 summarizes the effect on performance and seeker characteristics as the frequency is increased.

Table 2. Effect On Seeker Characteristics As Frequency Is Increased

Effect on Seeker Characteristics by Increasing Frequency	Advantage / Disadvantage	Source of Effect
• Decrease size and weight	Advantage	• Smaller and lighter components
• Improve detection of stealth targets • Increase Doppler resolution	Advantage	• Higher frequency particularly at millimeter wave frequencies
• Increase range resolution • Spread spectrum for ECCM	Advantage	• Larger bandwidth practical at millimeter wave frequencies
• Improve tracking accuracy • Increase angular resolution • Reduce multi-path and clutter • Higher gain • More jam resistant • Improve image quality and classification	Advantages	• Narrower beamwidth & lower sidelobes
• Decrease target search capability	Disadvantage	• Narrower beamwidth
• Increase atmospheric losses	Disadvantage	• Increase absorption and scattering
• Shorter Acquisition ranges	Disadvantage	• Less transmit power
• Increase cost and schedule risk	Disadvantage	• Technology less mature at higher frequencies (particularly at 94 GHz and higher)

3.0 MULTISENSOR DATA FUSION

Missile seekers employing sensor suites require an architecture for employing the outputs of more than one sensor. Complementary sensor characteristics, such as acquisition range versus tracking accuracy, can be exploited by sequential employment of sensors. In addition, simultaneous employment of multisensor data may be required to provide the margin of performance enhancement necessary to acquire and track challenging targets such as low observable - stealth targets at low altitude (see Figure 4). Section 5.0 describes the fundamentals of using sensor fusion for increased acquisition performance.

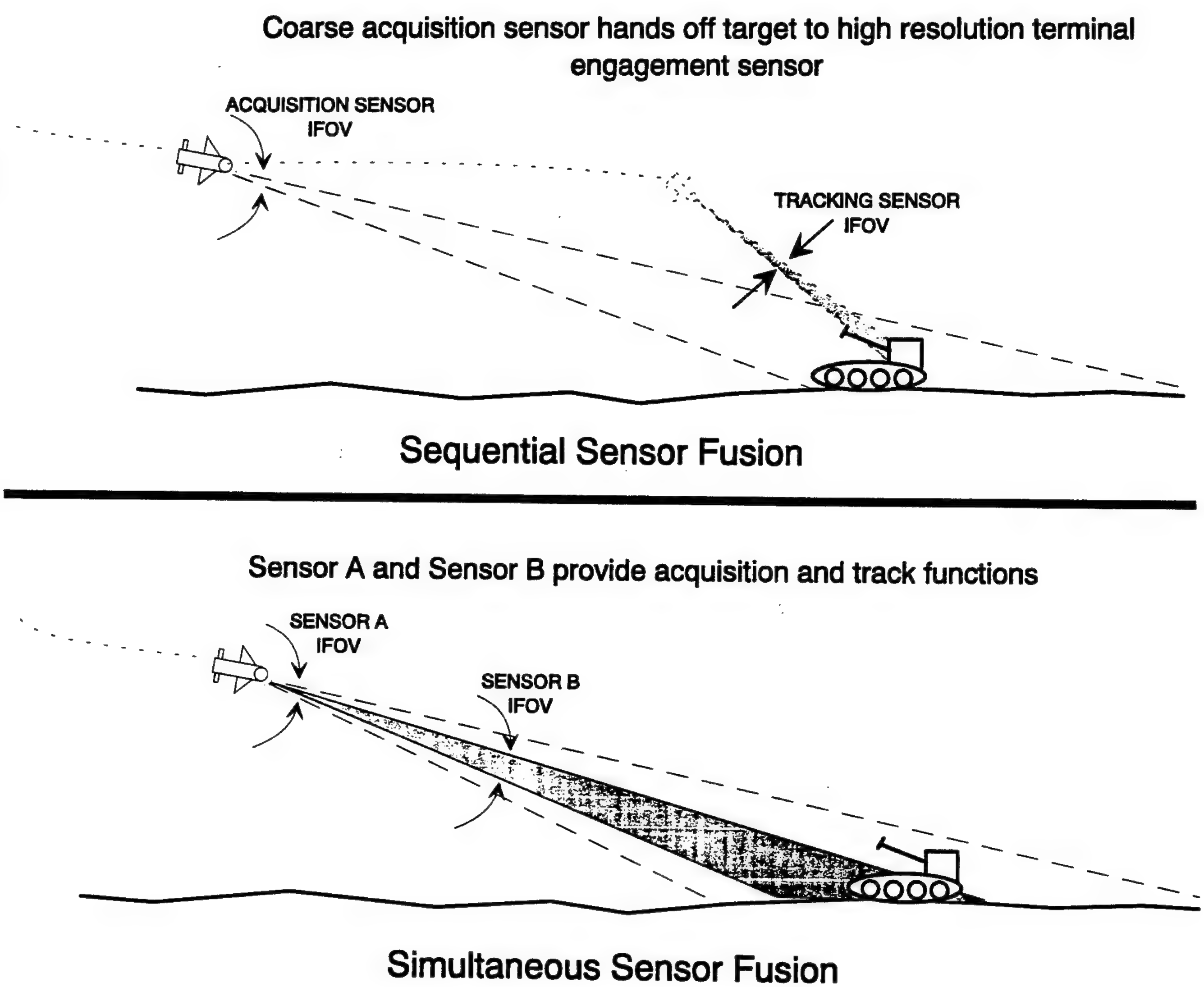


Figure 4. Sequential and Simultaneous Sensor Fusion

4.0 POTENTIAL MULTI-MODE/DUAL MODE CONCEPTS.

Often, due to the diversity of target and background sets, utilization of multi-mode/dual mode seeker concepts can be expected from industry. This would permit the missile to operate in a more diverse battle environment. There are numerous ways to implement multi-spectral seekers.

4.1 18 GHz (Ku band) Radar/ 8-12 μm or 3-5 μm Focal Plane Array

The primary employment mode for this sensor suite would be sequential with the radar acquiring the target at greater ranges and then handing off to the IR sensor for more accurate tracking in the end-game. The radar could shut down after hand-off for covertness. Alternately, the radar could actively track the target in concert with the IR sensor for improved track continuity in the event of countermeasure employment or a cloud obscured line-of-sight to the target.

For low observable targets at low altitude, target acquisition performance enhancement could potentially be realized via a sensor fused operating mode where detection decisions are based on combined radar/IR observations.

4.2 18 GHz (Ku band)/ 35 GHz (Ka band) Radar

The primary operating mode for this frequency diverse combination of radars would also be sequential. The 18 GHz frequency would be the primary frequency for acquisition with better ranging capability. The 35 GHz millimeter wave frequency would provide primary tracking for higher angular resolution. Frequency switching could be employed in a jamming environment. The MMW frequency could also prove useful in assisting the acquisition of heavily stealthed targets, since stealth techniques are usually aimed at microwave frequencies.

4.3 35 Gz (Ka band) Radar/ 8-12 μm or 3-5 μm Focal Plane Array

This combination of sensors offers the above cited advantages of millimeter wave frequencies compared to microwave frequencies at the cost of decreased radar acquisition range. Accordingly, this sensor suite would need to depend more heavily on a sensor fused mode of operation to raise the acquisition capability of the sensor suite above that of the individual sensors.

4.4 Option 4.1, 4.2, or 4.3 with Passive RF Radiometer

The addition of an RF radiometer to one of the radar/IR dual mode suites represents a potentially very powerful combination of sensors. The radiometer would be designed to detect microwave emissions from the target within the band from 2 to 18 GHz. This sensing capability could prove extremely valuable in acquiring emissions from the RF altimeters of terrain following cruise missiles. The radiometer could significantly augment the detectability of this type of low observable target whose response in the radar and IR channels will often be quite weak.

5.0 FUNDAMENTALS OF SENSOR FUSION

Sensors detect targets by measuring quantities associated with the target that are well-separated from the corresponding quantities associated with the background scene or other sources of interference. For example, Figure 5 shows that the radar signal returns from a target aircraft are usually greater in amplitude than the noise voltage in the radar receiver electronics. This separation between the radar measurements associated with target returns and those associated with receiver noise permits the placement of a detection threshold which effectively segregates the two "clusters" of measurements. When a radar measurement exceeds this threshold, a target can be declared present with high confidence.

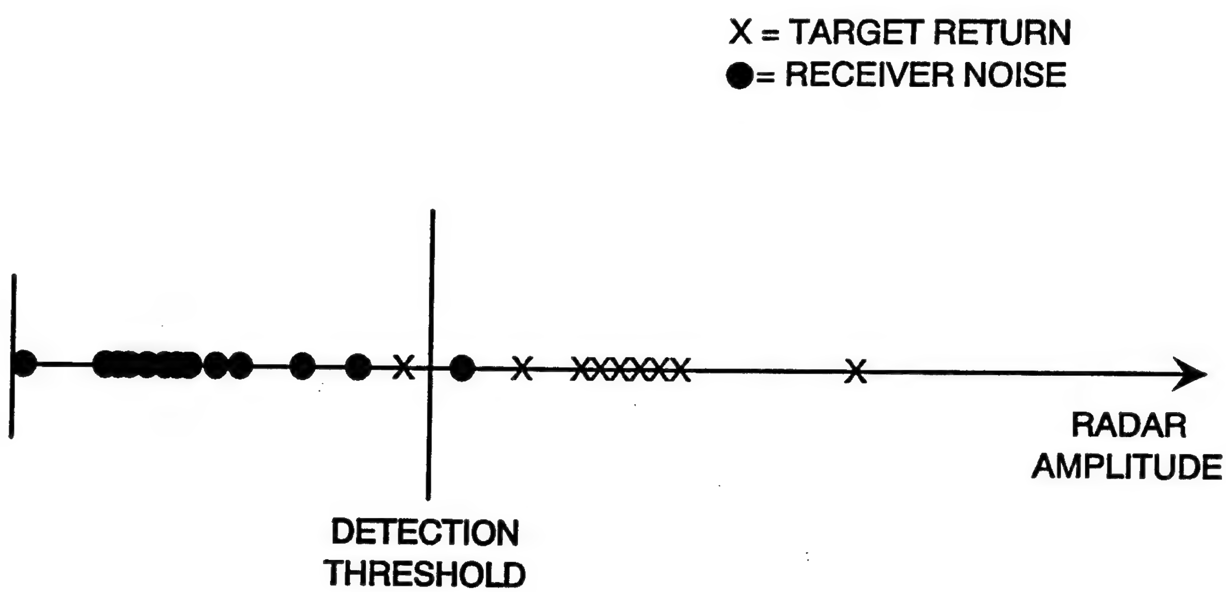


Figure 5. Examples of Radar Receiver Output Amplitude for Target Returns Compared to Receiver Noise

However, occurrences of usually large noise voltage can occasionally exceed the threshold (see Figure 5) resulting in the false indication of a target (i.e., a false alarm). Similarly, weak returns from a target may occasionally fall below the threshold resulting in a missed target. Accordingly, the radar designer minimizes the occurrence of false alarms and misses by maximizing the separation between the "clusters" of target and noise related measurements. Maximizing this separation is synonymous with maximizing the ratio of target signal power to noise power, i.e., maximizing the signal-to-noise ratio (SNR) that is commonly referred to in radar literature.

For an infrared (IR) sensor, the contrast in the intensity of IR radiation observed between the target and the background is usually greater than the contrast in the background scene (see Figure 6). This separation between IR measurements associated with a target and those associated with background clutter permits the placement of a detection threshold similar to the radar example just considered. Also, as in the radar case, it is possible for weak target contrast to fall below the threshold resulting in a missed target and for strong background clutter to exceed the threshold causing a false alarm. Again, designing the sensor to maximize the separation between the "clusters" of target and background contrast measurements will minimize the probability of making an erroneous decision and optimize the detection performance of the sensor.

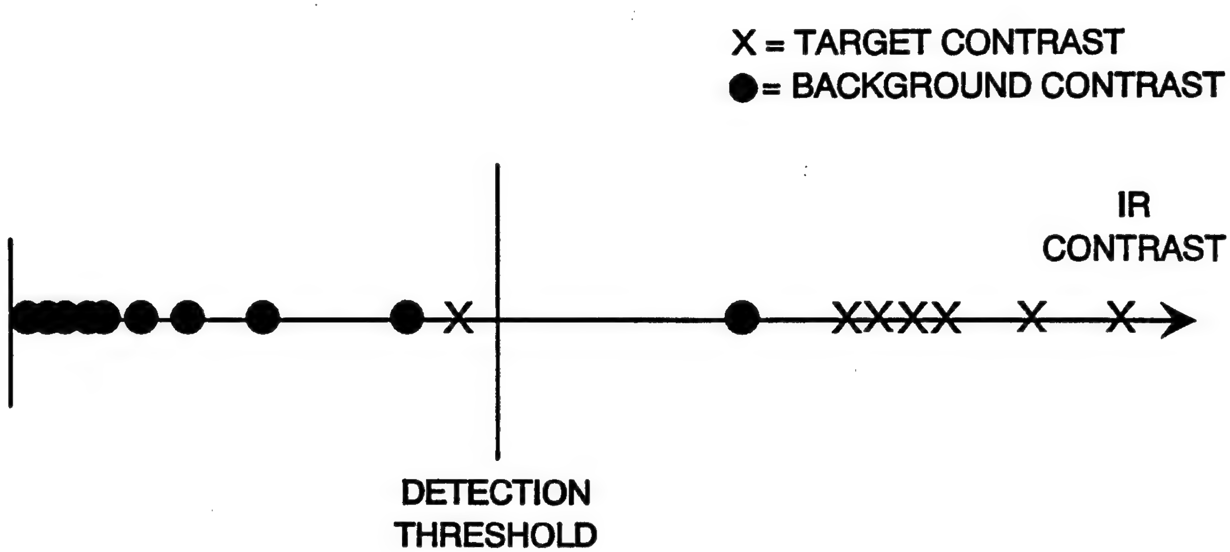


Figure 6. Examples of IR Contrast

Fusing synchronized sensor measurements together into a multidimensional observation is a means of achieving further separation between the "clusters" of target and interference measurements. This is apparent in Figure 7 where the sample radar and IR measurements from Figures 5 and 6 have been plotted as orthogonal coordinates. Associated radar and IR measurements are plotted 2- dimensionally (radar amplitude = x-component; IR contrast = y-component).

The separation between cluster centroids for the radar, IR, and fused measurements are indicated by the two-ended arrows in Figure 7. The increased cluster separation realized via fusion is merely a result of geometry - the magnitude of the vector separation is greater than any of its individual components.

It is this increased separation between target and interference related measurements that is the physical basis/source of detection performance enhancement for any implementation of a fused multisensor mode of operation. This increased separation effectively constitutes an increase in the signal-to-noise ratio upon which detection decisions are based. The increased separation makes it easier (compared to single sensor operation) to position a decision boundary which segregates target and interference related measurements into separate regions (see the dashed line in Figure 7). It then becomes less likely that a measurement associated with a weak target will fall below the decision boundary and cause a target to be missed. Similarly, it also becomes less likely that strong interference will rise above the boundary and cause a false alarm. Sensor fused operation thus holds the potential to simultaneously provide higher detection probability and lower false alarm probability than can be achieved with a single sensor.

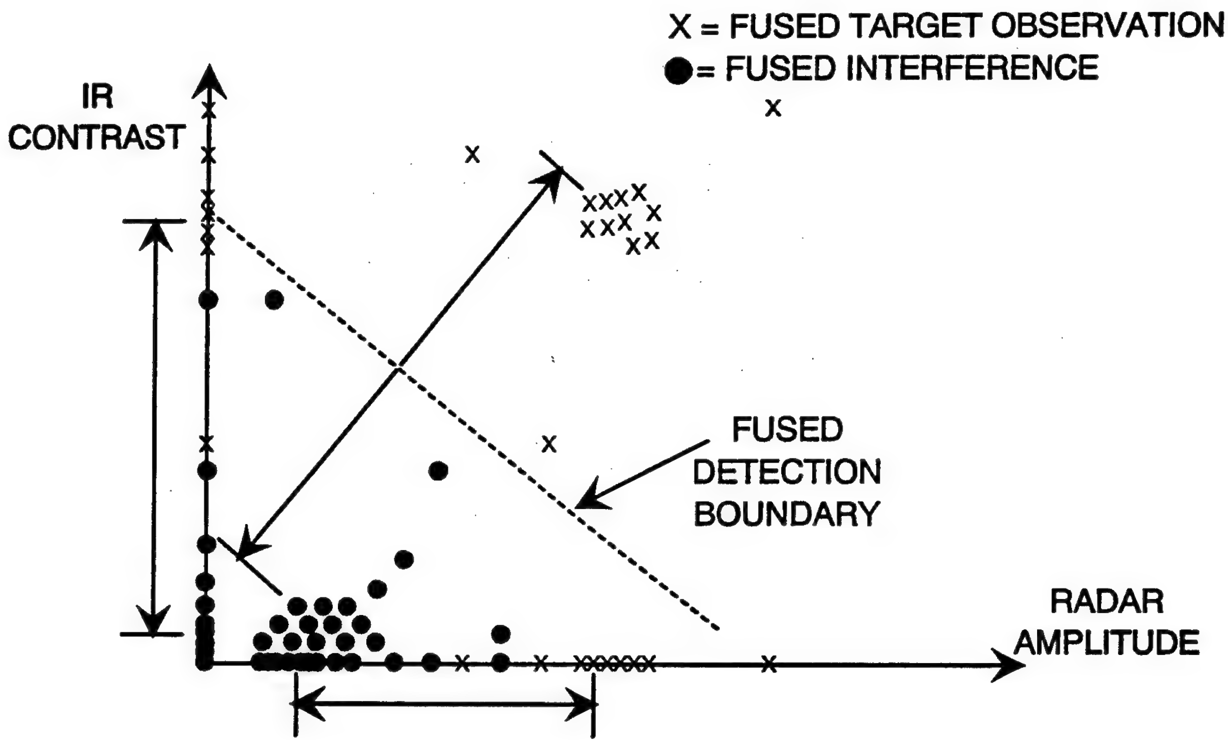


Figure 7. Fusion of Radar and IR Measurements into 2-D Observations

The multidimensional measurement space concept, shown in Figure 7, represents the fundamental analytical tool for bounding the maximum theoretical fused detection performance of a given sensor suite. This performance bound can be usefully employed as a yardstick to test the reasonableness of a contractor's fusion performance claims.

6.0 BATTLEFIELD PHENOMENA

There are many elements of modern day battlefields that can impact the performance of missile seekers. Of these elements, it can only take one for which the sensor was not designed can defeat an entire weapon system. All effects which could potentially be a factor on the battlefield should be considered when designing and developing specifications for missile sensors/seekers.

An understanding of all realistic battlefield phenomena is crucial for successful weapon employment, weapon survivability, and training. Appendix B contains executive charts illustrating four (4) areas of battlefield phenomena (i.e., weather effects, countermeasures, dirty battlefield, and camouflage, concealment, and deception (CCD)) and the impact on smart weapon sensors and seekers. The executive charts are a product of a series of studies sponsored by the U. S. Army Materiel Command - Smart Weapons Management Office (AMC-SWMO). The primary purpose of these studies has been to identify and categorize the phenomena and develop a methodology to assess their impact.

The first study focused on the impact of weather on smart weapon sensors/seekers. One of the main objectives of this study was to present a concise methodology for preparing weather specification for sensors associated with smart weapon systems. The "Smart Weapons Weather Specification Guide", AMC-SWMO, 31 October 1990 was produced to outline the procedure. Another product from the study included a wall chart entitled "Weather Effects on EO/IR/MMW Sensors" which is included in appendix B.

Countermeasures (CMs) were the focus of the second study "AMC-SWMO Countermeasures Study, Volume I: Guide to How Countermeasures Affect Smart Weapons", January 1992. There were two primary objectives of this study - to address several technical issues on the effects of CMs on smart weapon systems and to introduce the organizations that are key in the specification, development, and evaluation of smart weapon CMs. The technical issues included a description of the various CMs, a methodology to assess the impact of CMs on

smart weapon systems, and the application of this methodology to five specific systems. The executive wall chart titled "Countermeasure Effects on Smart Weapon Sensors" was developed and is included in appendix B.

A third study addressed the effects of battle by-products on smart weapon sensors. Battle by-products is defined as "the phenomena produced by military operations that unintentionally reduce the operational effectiveness of an activity or capability". A methodology was developed to assess the impact of the battle by-products on smart weapon sensors and seekers. Several effectiveness models and phenomenology models and databases were reviewed to assess their applicability to the methodology. This was not a model survey; it was an assessment of several accepted models to demonstrate how to utilize available tools in the methodology. The methodology was then applied to two representative smart weapon concepts. Results of this study are documented in a two-volume report "The Effects of Battle By-Products on Smart Weapon Sensors", AMC-SWMO, March 1994, and an executive wall chart which is included in appendix B.

The fourth study also produced an executive wall chart included in appendix B titled "Camouflage, Concealment and Deception (CCD) Effects on Smart Weapons Sensors", AMC-SWMO. The purpose of the wall chart is to provide basic information on the Government CCD organization, the CCD development cycle and CCD techniques as they relate to the operation of smart weapons sensors.

7.0 SUMMARY

There is no "one" perfect sensor technology to be used in a missile seeker. The environment, target signature, background and countermeasures as well as size, cost and complexity constraints require many engineering tradeoffs leading to the final selection of seeker operating spectrum(s). It is generally accepted that the use of more than one seeker spectrum for a particular mission broadens the operational envelope.

Appendix A

Electromagnetic Spectrum

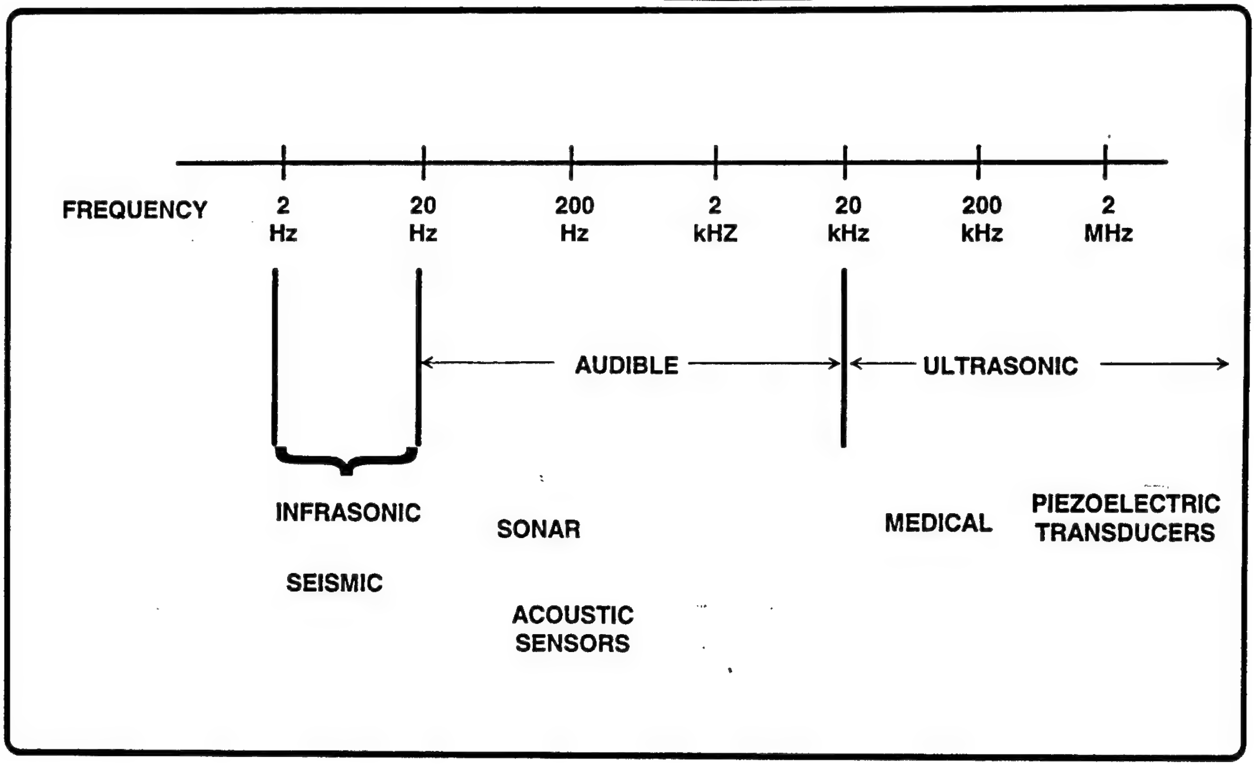


Figure A-1. Acoustic (Mechanical) Spectrum

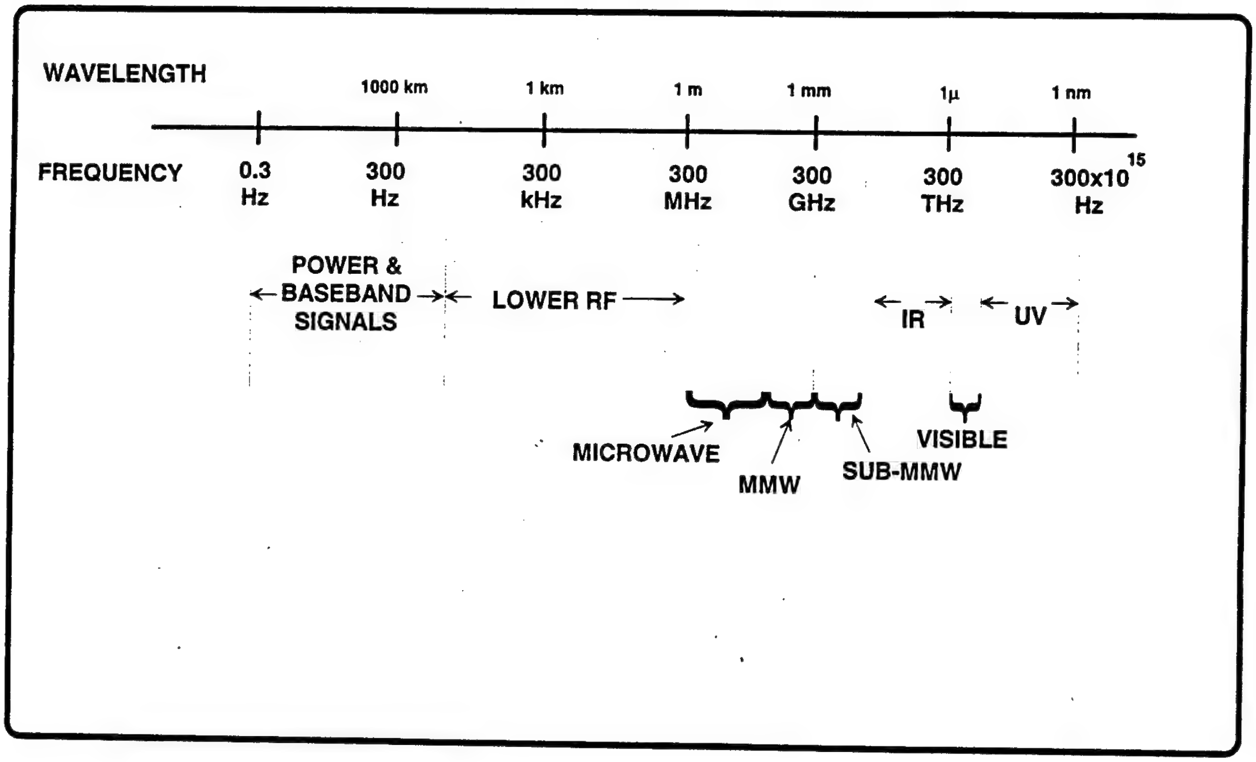
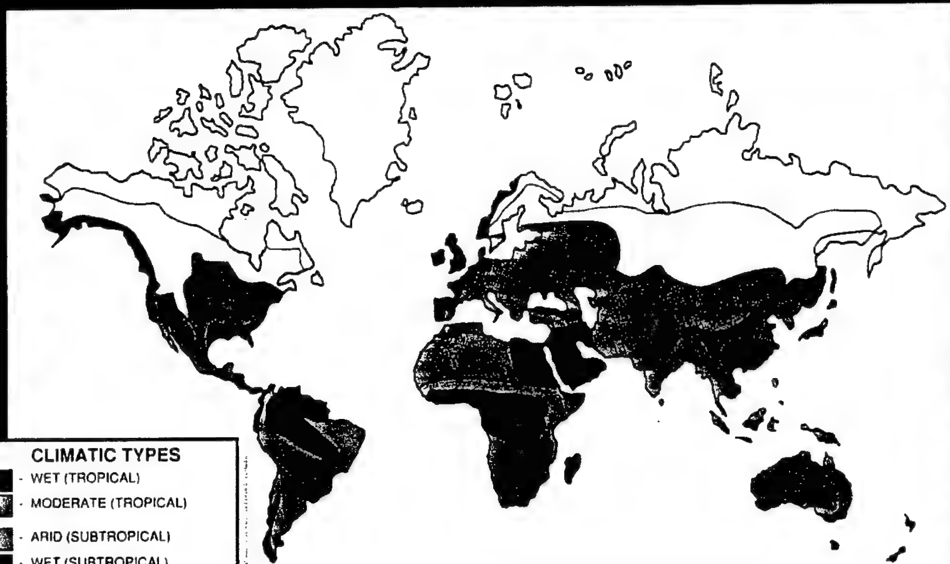


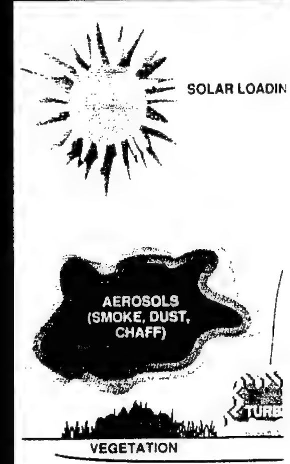
Figure A-2. Electromagnetic Spectrum

Appendix B

Executive Wall Charts

WEATHER EFFECTS (





CLIMATIC TYPES

- WET (TROPICAL)
- MODERATE (TROPICAL)
- ARID (SUBTROPICAL)
- WET (SUBTROPICAL)
- CONTINENTAL (TEMPERATE)
- MARITIME (TEMPERATE)
- TIAGA (MODERATE)
- TUNDRA (DRY)

SAMPLE CLIMATIC REGIONS

- CENTRAL AMERICA (ATLANTIC SIDE) - TYPICAL OF *WET* (TROPICAL) CLIMATIC TYPE
- EUROPEAN LOWLANDS - TYPICAL OF *MARITIME* (TEMPERATE) CLIMATIC TYPE
- MIDEAST DESERTS - TYPICAL OF *ARID* (SUBTROPICAL) CLIMATIC TYPE

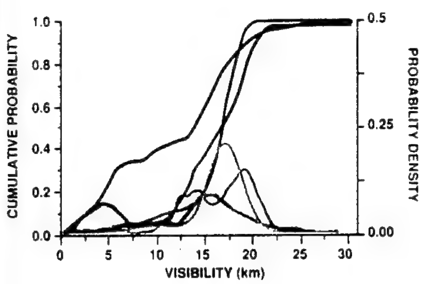
WEATHER PARAMETERS	VISIBLE AND NEAR
LOW VISIBILITY	SEVERE
RAIN/ SNOW	MODERAT
HIGH HUMIDITY	LOW
FOG/ CLOUD	SEVERE
PHOSPHORUS/ DUST	SEVERE
FOG OIL/ SMOKE	SEVERE
SYSTEMS	 DAYSIGHT TVs AN/PVS- AN/PVS- AN/TVS- AN/TVS- AN/TVS-

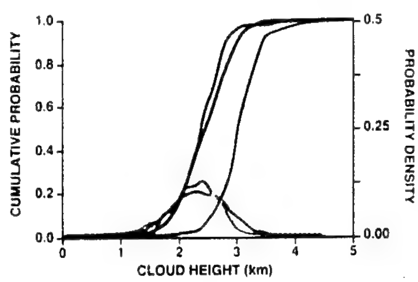
CUMULATIVE PROBABILITY OF OCCURRENCE YIELDS THE PROBABILITY THAT THE WEATHER PARAMETER WILL BE AT THE INDICATED VALUE OR LESS

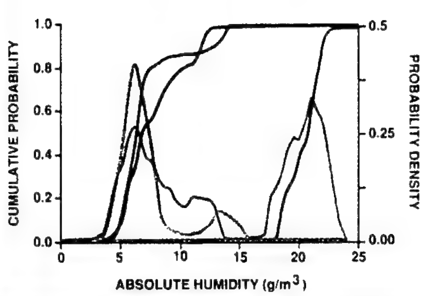
- CENTRAL AMERICA (ATLANTIC SIDE)
- EUROPEAN LOWLANDS
- MIDEAST DESERTS

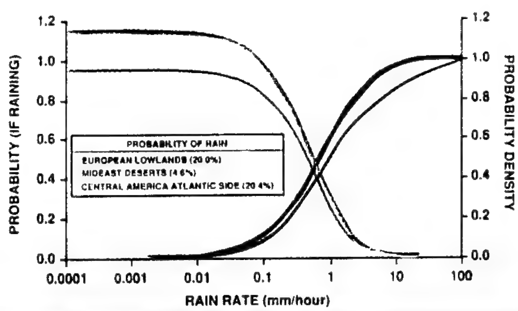
SOLID LINES - CUMULATIVE PROBABILITY

SHADED LINES - PROBABILITY DENSITY









GOVERNMENT

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SMART WEAPONS MAN
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Prepared by:

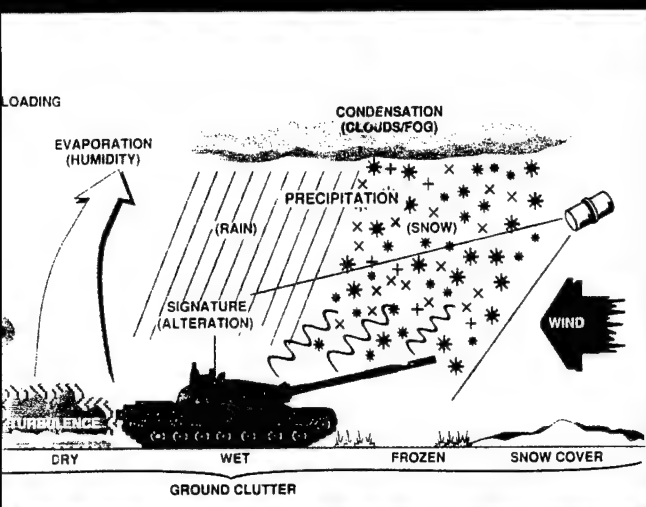
Dynetics, Inc. an employee owned company
Huntsville, Alabama

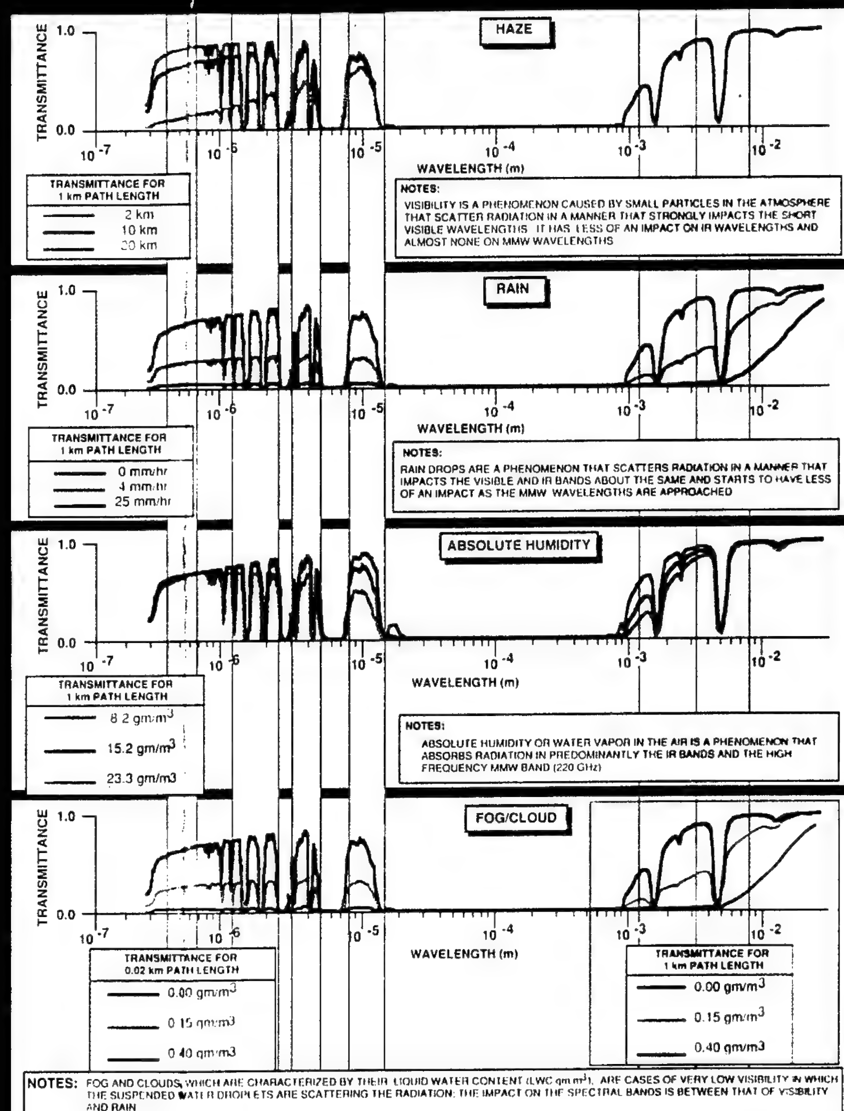
For:

AMC-SWMO
UNDER CONTRACT NUMBER: DAAH01-89-D-0069

I

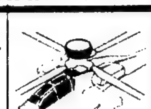
ON EO/IR/MMW SENSORS



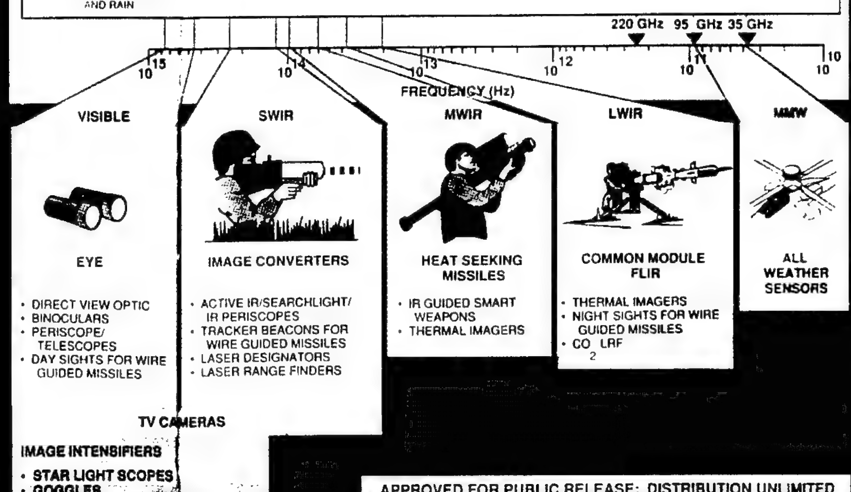


SIBLE NEAR IR	SHORTWAVE IR	MIDWAVE IR	LONG WAVE IR	MMW
VERE	MODERATE	LOW	LOW	NONE
ERATE	MODERATE	MODERATE	MODERATE	MODERATE/ LOW
OW	LOW	MODERATE	MODERATE	LOW/NONE
VERE	SEVERE	MODERATE/ SEVERE	MODERATE/ SEVERE	MODERATE/ LOW
VERE	SEVERE/ MODERATE	MODERATE	MODERATE	LOW/ NONE
VERE	MODERATE	LOW	LOW	NONE

SOURCE: USA ATM SCIENCE LAB

				
SIGHTS TVs /PVS-4 /PVS-5 /TVS-4 /TVS-5 /TVS-2	TOW/DRAGON TRACKERS GLLD AN/GVS-5 ACTIVE IR PERISCOPE	STINGER REDEYE AN/PAS-7	AN/TAS-4 AN/TAS-5 AN/TAS-6 AN/VSG-2	LONGBOW

SOURCE: JANES WEAPON SYSTEMS



NT AGENCIES

MANDER
TERIEL COMMAND
MANAGEMENT OFFICE
AMSMI-SW
RSENAL, AL 35898

COMMANDER/DIRECTOR
US ARMY ATMOSPHERIC SCIENCES LABORATORY
ATTN: SLCAS-AE
WHITE SANDS MISSILE RANGE, NM 88002

US AIR FORCE
ENVIRONMENTAL TECHNICAL
APPLICATIONS CENTER
SCOTT AFB, IL 62225

GEOPHYSICS LABORATORY
AIR FORCE SYSTEMS COMMAND
US AIR FORCE
HANSCOM AFB, MA 01731

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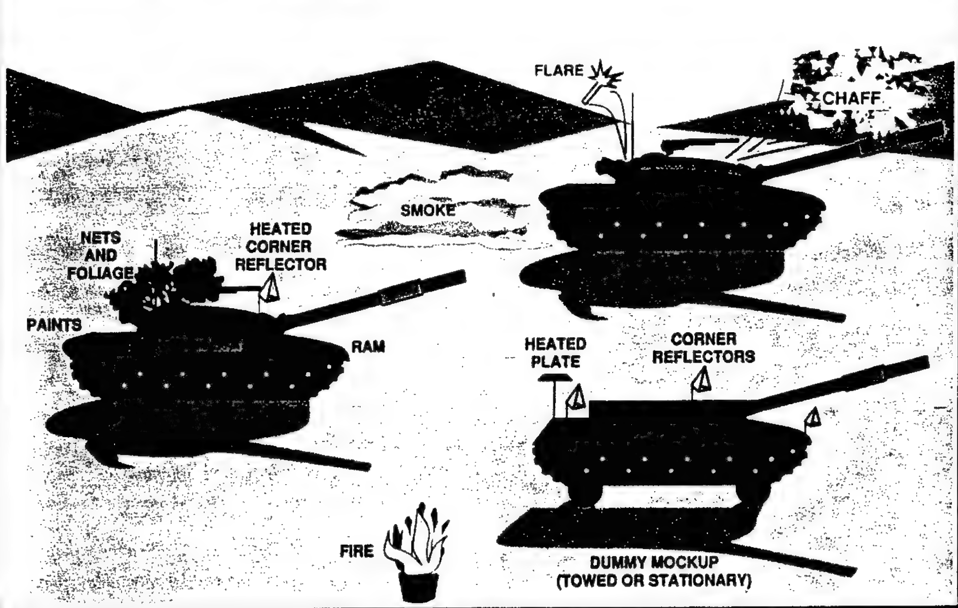
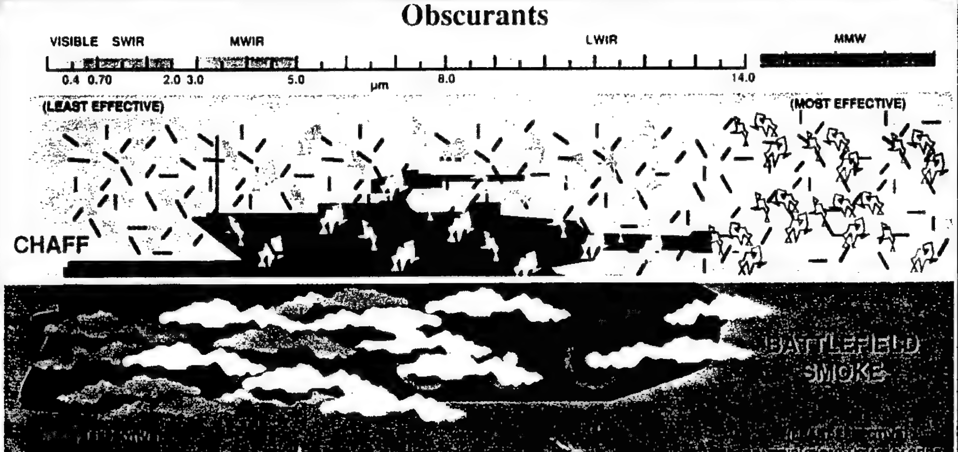
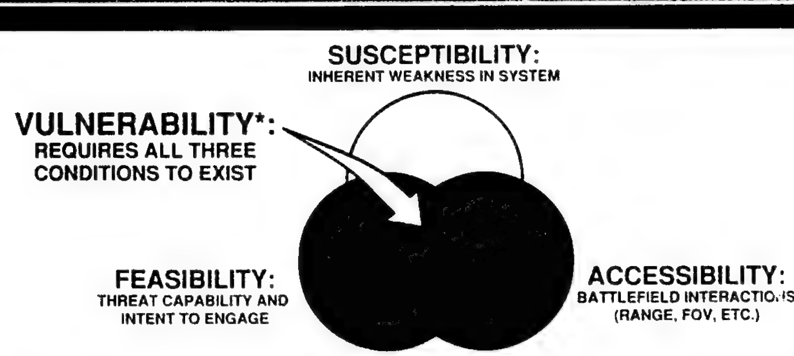
COUNTERMEASURE EFFECT

Signature Alteration and Deception



Obscurants





* EW VULNERABILITY INCLUDES A FOURTH CIRCLE - INTERCEPTABILITY

Prepared by:
Dynetics, Inc.
HUNTSVILLE, ALABAMA

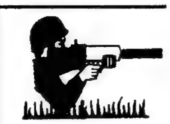
For: **AMC-SWMO**
UNDER CONTRACT NUMBER:
DAAH01-89-D-0069

Examples of Countermeas Spectral Regio

● - HIGHER DEGREE OF CONCERN
◐ - MODERATE DEGREE OF CONCERN
○ - LOWER DEGREE OF CONCERN

	VISIBLE 0.4 to 0.7 μm	SWIR 0.7 to 2.0 μ
SIGNATURE ALTERATION	FOLIAGE CAMOUFLAGE PAI CAMOUFLAGE NET	
DECOYS/ DECEPTION	MOCKUP REPLICA SMOKE	
OBSCURANTS	FOG, OIL, SMOKE PHOSPHORUS	
DEWs / JAMMERS	SOLID-STATE LASE	

VISIBLE	SWIR
EYE TV CAMERA	LASER TRACKERS
• DIRECT VIEW OPTIC • BINOCULARS • PERISCOPES/ TELESCOPES • DAY SIGHTS FOR WIRE GUIDED MISSILES	• ACTIVE IR/SEARCHLIGHT IR PERISCOPES • TRACKER BEACONS FOR WIRE GUIDED MISSILES • LASER DESIGNATORS • GOGGLES • IMAGE CONVERTERS



Survivability An

CATEGORY	NAME	DEFI
I	ROUTINE	DCSINT app have a high being enco
II	LESS FREQUENT	DCSINT app have a low t probability encountere
III	POTENTIAL	CMs that ar technically feasible but approved.

APPROVED FOR PUBLIC

IV

CTS ON SMART WEAPON SENSORS

ermeasure Types and Effective Region of Operation

SPECTRAL BANDS: SWIR 0.7 to 2.0 µm · MWIR 3.0 to 5.0 µm · LWIR 8.0 to 12.0 µm · MMW 95 GHz / 35 GHz

SMART WEAPON FUNCTION

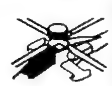
Countermeasure	DISPENSE	ACQUIRE	AIMPOINT TRACKING
LIAGE		●	
LAGE PAINT		●	
LAGE NETS		●	
REDIRECT ENGINE EXHAUST		●	◐
HOT SPOT MASKING		●	◐
RAM		●	
P REPLICAS		●	
SMOKE			◐
HEATED PLATES/CORNER CUBES		●	◐
FLARES			◐
CHAFF		●	◐
IL, SMOKE		●	○
PHORUS SMOKE/DUST/BURNING OIL		●	◐
ADVANCED SMOKES		●	◐
CHAFF		●	○
HOT SPOT BEACONS		●	●
RF EMITTERS	●	●	●
ATE LASERS / CO_2 LASERS		●	◐
HIGH-POWER MICROWAVE	●	●	◐

VIR · MWIR · LWIR · MMW

ACKERS
EARCHLIGHT/
ES
EACONS FOR
D MISSILES
GNATORS
ERTERS

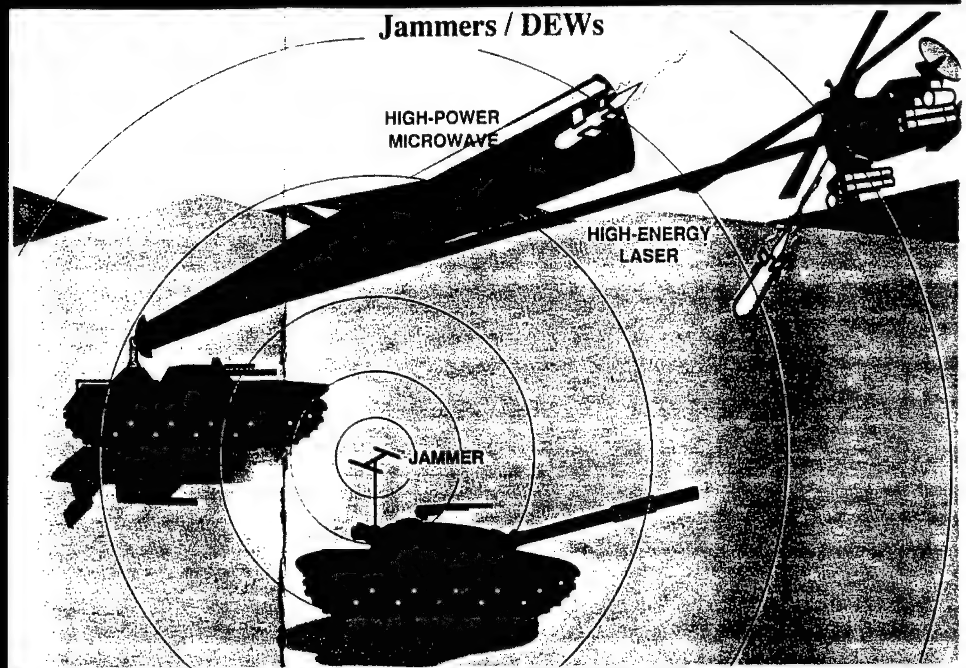
HEAT SEEKING MISSILES
- IR GUIDED SMART WEAPONS
- THERMAL IMAGERS

COMMON MODULE FLIR
- THERMAL IMAGERS
- NIGHT SIGHTS FOR WIRE GUIDED MISSILES
- CO_2 LRF



ALL WEATHER SENSORS
- MMW GUIDED SMART WEAPONS

Jammers / DEWs



ity Annex CM Category Definitions

DEFINITION	IMPLICATION
CSINT approved CMs that ve a high probability of ing encountered.	Performance levels specified in the presence of CMs are required in the first production.
CSINT approved CMs that ve a low to medium obability of being countered.	Performance levels specified in the presence of CMs are required in the first production. (Performance levels may not be as stringent as would be required against Category I CMs).
Ms that are judged to be chnically and tactically asible but are not DCSINT proved.	Performance levels in the presence of CMs may be required in the first production. A P^3I program should be prepared as a minimum.

SOURCE: US ARMY SMO, VAL, VLAMO (25 JUN 1991)

Countermeasures and Survivability Community

EVALUATIONS: TRAC · OPTEC · AMSAA

SMO
DCSINT
INSCOM
AIA
- MSIC
- FSTC
- ITAC

FID/FIO

REQUIREMENTS: Proponent Combat Developer

Smart Weapon PMs PEOs
PEO ASM
PM Survivability

ASSESSMENTS: VLAMO · BRL · CHEM RDEC

SUPPORT: VAL

AMC SWMO

TECHNICAL SUPPORT, INTEGRATION AND COORDINATION

[illegible] Centers [illegible]

Chicken Little JPO

TRADOC
INTELLIGENCE
ARMY MATERIEL COMMAND

COMMANDER
US ARMY MATERIEL COMMAND
SMART WEAPONS MANAGEMENT OFFICE
(AMC-SWMO)
ATTN: AMSMI-SW
REDSTONE ARSENAL, AL 35898

30 JUNE 1991

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X

EFFECTS OF BATTLE BY-PRODUCT

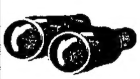
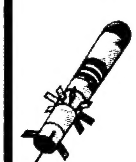
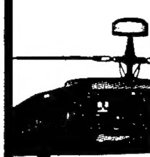
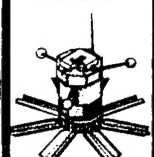
BATTLE B

BATTLE BY-PRODUCTS
SENSOR PERFORMANCE TH
OR TARGET SIG

RELATIVE IMPACT OF BATTLE BY-PRODUCTS

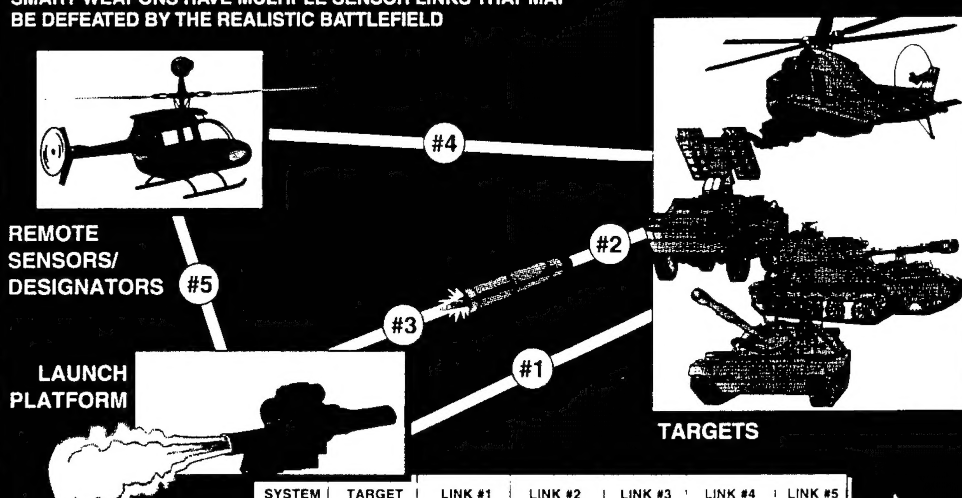
	BATTLE BY-PRODUCT	SENSOR						
		VISIBLE	SWIR	MWIR	LWIR	MMW	ACOUSTIC -SEISMIC	MAGNETIC
PATH EFFECTS	DUST							
	SMOKE							
	PLUMES							
CLUTTER	EMI							
	EXPLOSIONS							
	HULLS							
	FIRES							

LEGEND: LOW SEVERE

VISIBLE	SWIR	MWIR	LWIR	MMW	ACOUSTIC -SEISMIC	MAGNETIC
						
• DIRECT VIEW OPTICS • BINOCULARS	• LASER DESIGNATORS • ACTIVE IR/ SEARCHLIGHT • TRACKER BEACONS • IMAGE CONVERTERS	• IR GUIDED WEAPONS • THERMAL IMAGERS	• THERMAL IMAGERS • CO_2 LRF	• MMW GUIDED WEAPONS	• COARSE ACQUISITION SENSORS	• WARHEAD FUZING/TARGET CONFIRMATION

SMART WEAPON SENSOR LINKS

SMART WEAPONS HAVE MULTIPLE SENSOR LINKS THAT MAY BE DEFEATED BY THE REALISTIC BATTLEFIELD

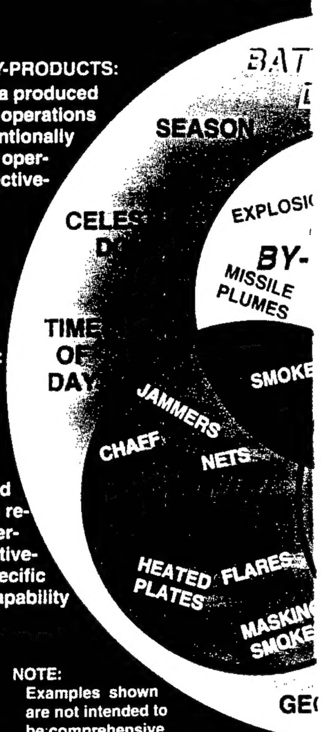


SYSTEM	TARGET	LINK #1	LINK #2	LINK #3	LINK #4	LINK #5
TOW 2B	ARMOR GND. VEH	FLIR 8 - 12 VISIBLE	SWIR 0.9 MAGNETIC	SWIR 0.9 FLIR 8 - 12 WIRE		
HELLFIRE	ARMOR GND. VEH.	FLIR 8 - 12 VISIBLE LASER 1.06	LASER 1.06		FLIR 8 - 12 LASER 1.06	COMM LINK (RADIO)

RELATIONS BATTLEF

BATTLE BY-PRODUCTS: Phenomena produced by military operations that unintentionally reduce the operational effectiveness of an activity or capability

COUNTER-MEASURES: Devices, techniques or actions that are intentionally designed and employed to reduce the operational effectiveness of a specific activity or capability



NOTE: Examples shown are not intended to be comprehensive

Prepared by:
Dynetics, Inc.
Huntsville, Alabama

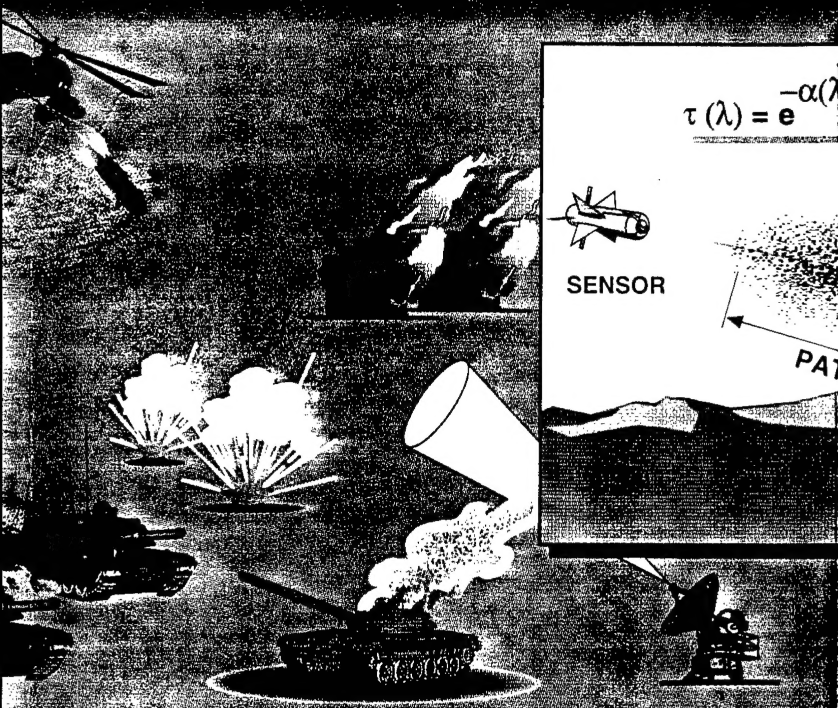
For:
AMC-SWMO
UNDER CONTRACT NUMBER:
DAAH01-93-D-R001

VI

DUCTS ON SMART WEAPON SENSORS

BATTLE BY-PRODUCTS

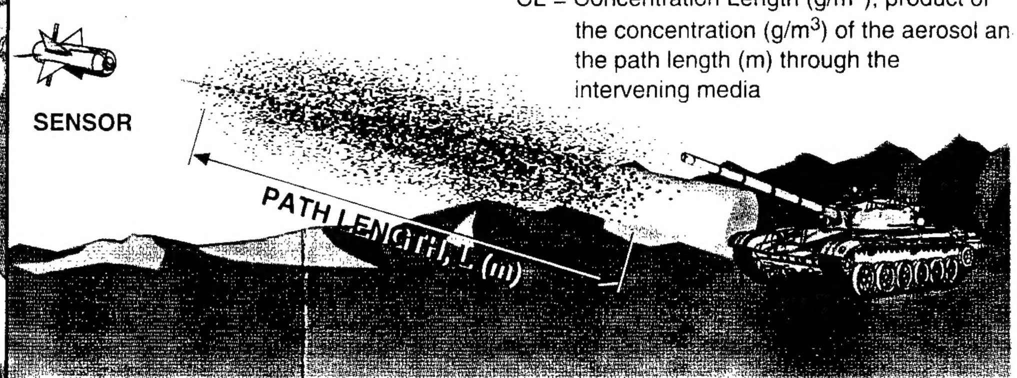
TLE BY-PRODUCTS CAN IMPACT SMART WEAPON
I PERFORMANCE THROUGH PATH EFFECTS, CLUTTER,
OR TARGET SIGNATURE ALTERATION



TRANSMISSION THROUGH BATTLE BY-PRODUCT OBSCURANTS

$$\tau(\lambda) = e^{-\alpha(\lambda)\,CL}$$

τ = Transmittance
λ = Wavelength (μm)
α = Mass Extinction Coefficient (m^2/g)
CL = Concentration Length (g/m^2), product of the concentration (g/m^3) of the aerosol an the path length (m) through the intervening media



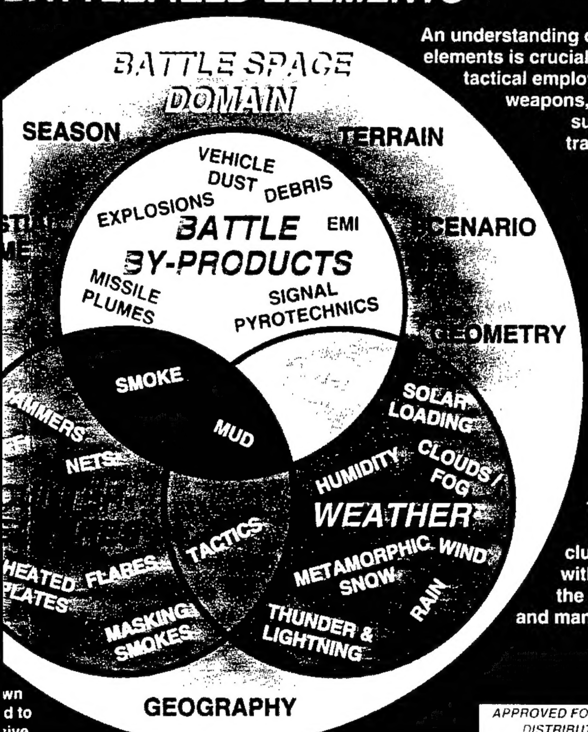
TYPICAL VALUES OF MASS EXTINCTION COEFFICIENT (m^2/g)

OBSCURANT TYPE	SPECTRAL BAND				
	VISIBLE 0.4 - 0.7 μm	SWIR 0.7 - 1.2 μm	MWIR 3 - 5 μm	LWIR 8 - 12 μm	MMW 35 / 94 GHz
BURNING DIESEL FUEL	6.40	3.69	1.34	1.00	----
PARTICULATE CARBON	1.50	1.46	0.75	0.32	0.001
VEHICULAR DUST	0.32	0.30	0.27	0.25	0.001
HIGH EXPLOSIVE DUST	0.32	0.29	0.27	0.26	0.001
PHOSPHORUS SMOKE	4.08	1.77	0.29	0.38	0.001
LOFTED SNOW	0.32	0.30	0.27	0.25	0.005-0.1

SOURCE: 61 JTCG/ME-87-10 AND DOD-HDBK-178 (E

ELATIONSHIP OF REALISTIC BATTLEFIELD ELEMENTS

An understanding of all battlefield elements is crucial for successful tactical employment of smart weapons, smart weapon survivability, and training of troops



WEATHER:
The natural state of the atmosphere including its interaction with other elements of the naturally occurring and manmade environment

wn
d to
tive

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REDSTONE ARSENAL, AL 35898-5222

VII

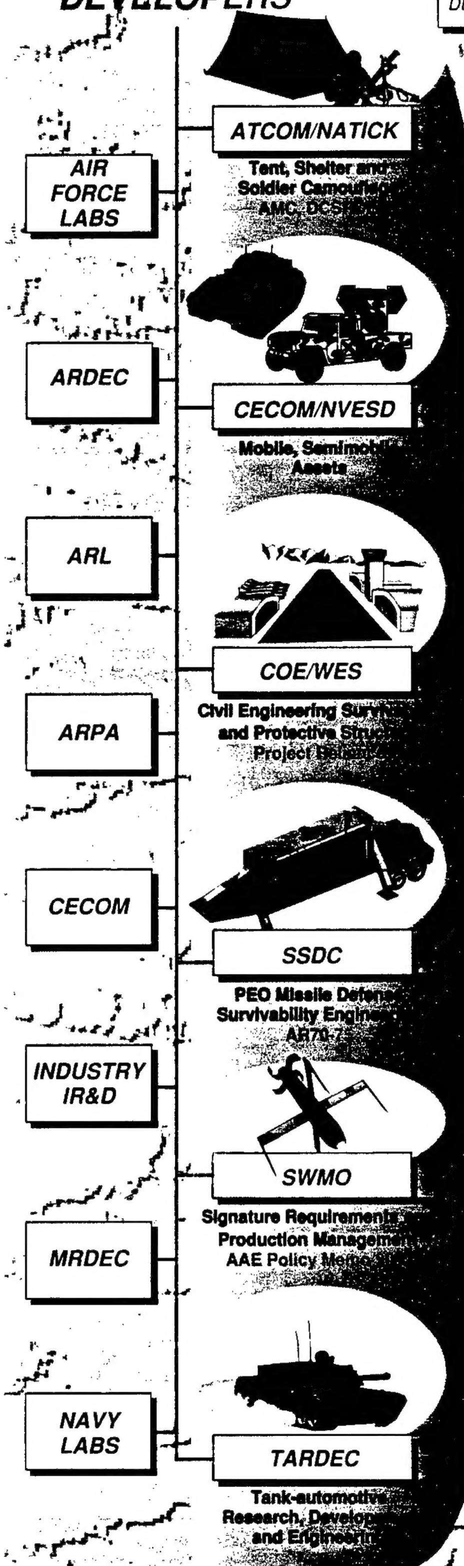
CCD TECHNOLOGY DEVELOPERS

CAMOUFLAGE, CONCEAL
EFFECTS ON SMA

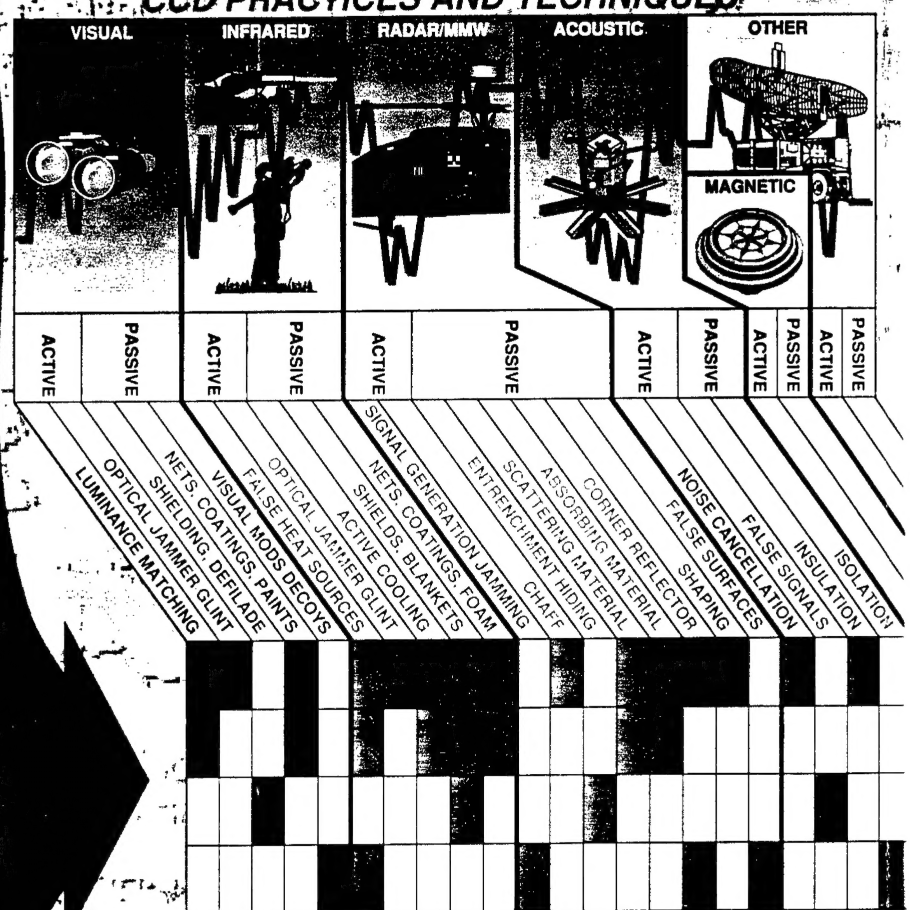
CAMOUFLAGE, CONCEALMENT, AND DECEPTI

Camouflage - The use of concealment and disguise to minimize the possibility of detection and/or identification of troops, n
Concealment - Protection from observation or surveillance
Deception - Measures designed to mislead enemy forces by manipulation, distortion, or falsification of evidence to induce t
to their interests

DEPARTMENT OF DEFENSE DICTIONARY OF MILITARY AND ASSOCIATED TERMS (Joint Chiefs of Staff Publication



CCD PRACTICES AND TECHNIQUES



THE SURVIVABILITY EQUATION

$$1 - ((P_l) \times P(d/l) \times P(r/d) \times P(h/r) \times P(k$$

Probability of Location	(x)	Probability of Detection Given Location	(x)	Probability of Recognition Giv
Finding the Target Area on the Battlefield	→	Detecting a Target within that Area	→	Recognizing the Class of (i.e. Truck, Tank, Buildir Defense Site, etc.)
SMART WEAPON FUNCTIONS		DETECTION		CLASSIFICATIO

Prepared by: BRC BEVILACQUA RESEARCH CORPORATION Huntsville, Alabama

For: AMC-SWMO U.S. ARMY UNFUNDED STUDY PROGRAM

VIII

...LMENT, AND DECEPTION (CCD) ...ART WEAPON SENSORS

...PTION (CCD)

...oops, materiel, equipment and installations

...nduce them to react in a manner prejudicial

...cation [JCS Pub 1], 1 June 1979)

SMART WEAPONS SYSTEM REQUIREMENTS

INTEL | CINCs | TRADOC | AFSC/ NAVSEA/ NAVAIR

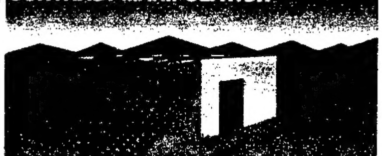
FUZING ◄ TRACKING ◄ GUIDANCE ◄ CLASSIFICATION ◄ DETECTION

SMART WEAPONS PEOs, PMs, SPOs

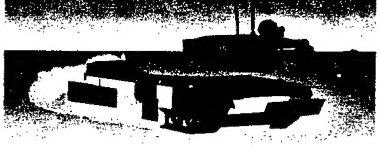
IMPACT ON SMART WEAPONS

CCD CATEGORIES

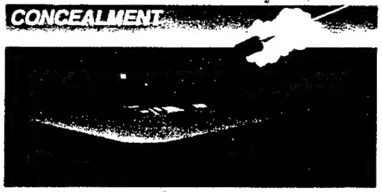
CONTRAST MANIPULATION



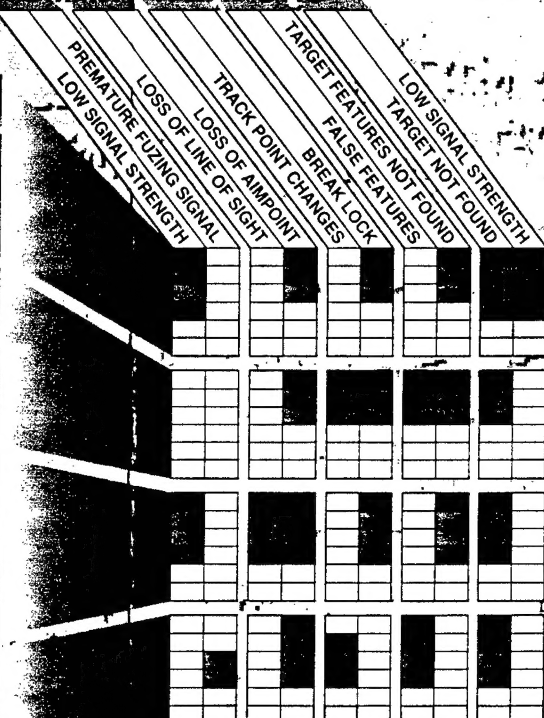
SPATIAL MANIPULATION



CONCEALMENT



DECEPTION



TECHNOLOGY EVALUATORS

- AFSC/ CHICKEN LITTLE
- AMSAA
- ARL
- NATIONAL LABS
- SWMO
- TECOM
- TEXCOM

...P(k/h)) = SURVIVAL PROBABILITY

...on Given Detection (x) Probability of Hit Given Recognition (x) Probability of Kill Given Hit

...ass of Target ...Building, Air ...e, etc.) → Hitting a Vulnerable Aimpoint on the Target with the Weapon → Damage Beyond Field Repair Level

...ATION | TRACK GUIDANCE | FUZING

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